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Shingai et al.

(54) **DISPLAY DEVICE AND DISPLAY SYSTEM**

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(52) **U.S. Cl.** **345/647**

(57) **ABSTRACT**

A display device includes a display part that displays an image; and a control part that causes the display part to perform a bending motion in accordance with the display image, the control part is configured to cause the display part to perform a bending motion in accordance with an image so as to further increase the degree of attention, the control part causes the display part to perform a bending motion by driving an actuator attached to the display part, and the display part is bent into various shapes by attaching a plurality of actuators to the display part and causing the control part to selectively drive the plurality of actuators.

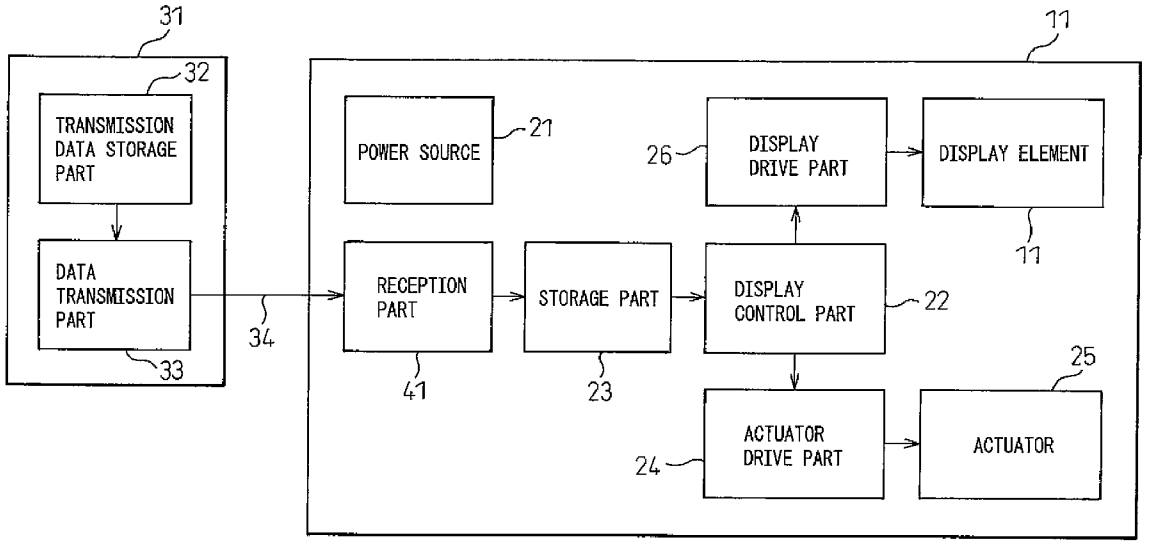


FIG.1A

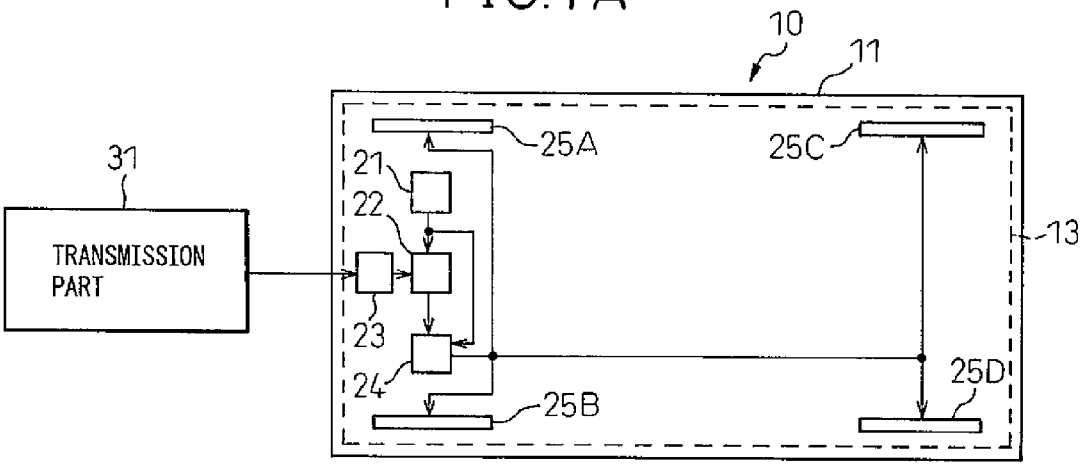

10
11
31
TRANSMISSION PART
21
22
23
24
25A
25B
25C
25D
13

FIG.1B

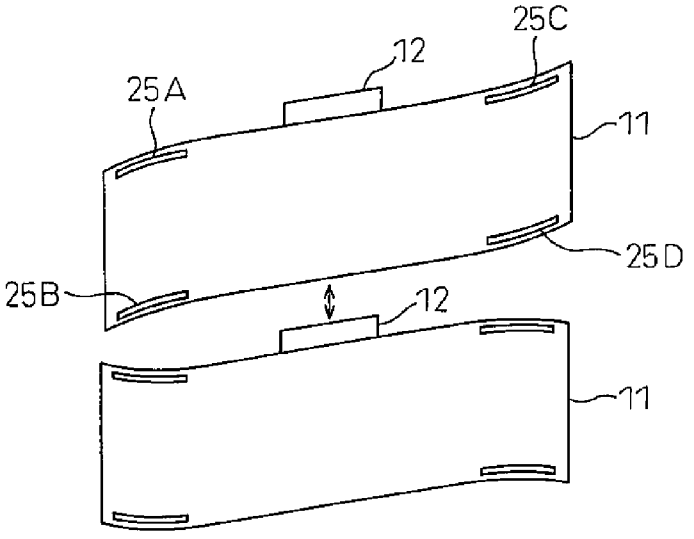

25C
12
25A
11
25D
25B
12
11

FIG.1C

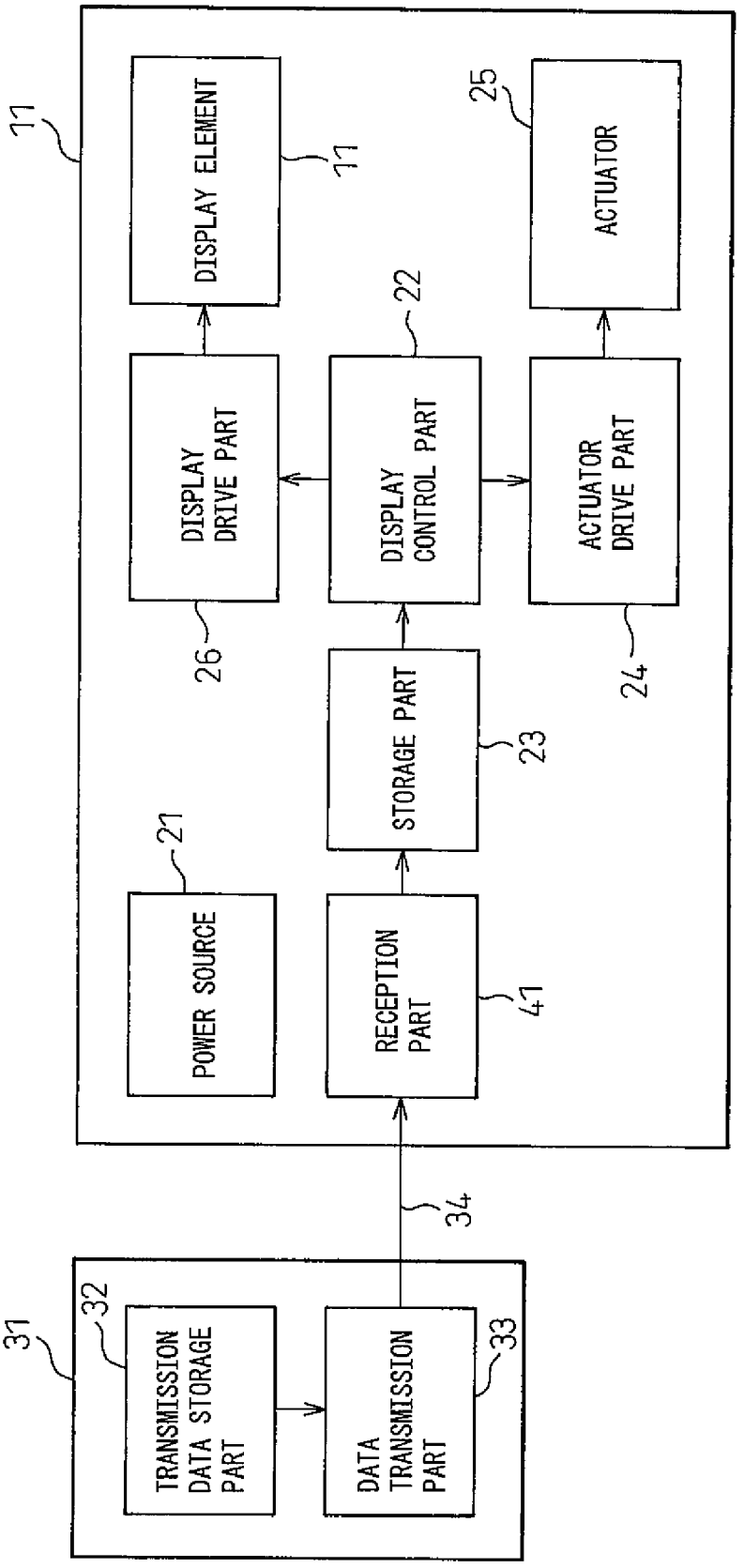

11
DISPLAY ELEMENT
17
25
ACTUATOR
22
DISPLAY DRIVE PART
DISPLAY CONTROL PART
ACTUATOR DRIVE PART
26
24
STORAGE PART
23
21
POWER SOURCE
RECEPTION PART
41
34
31
32
TRANSMISSION DATA STORAGE PART
DATA TRANSMISSION PART
33

FIG.2

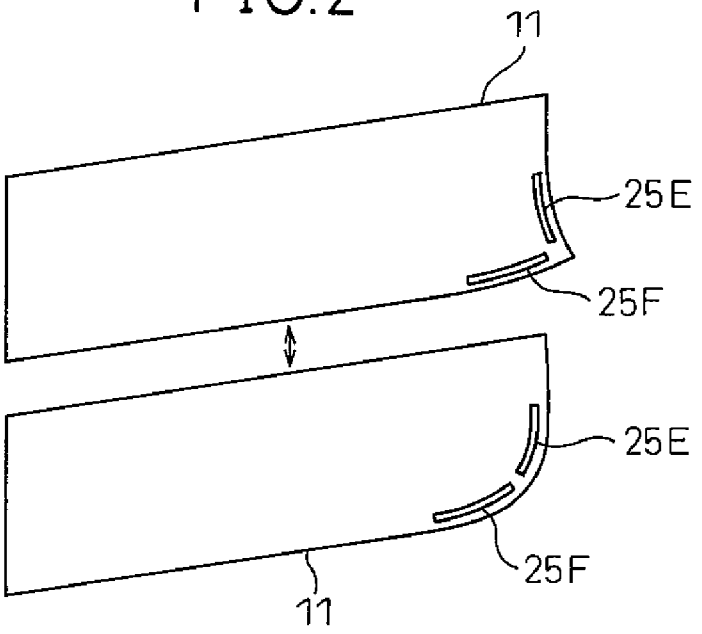


FIG.3

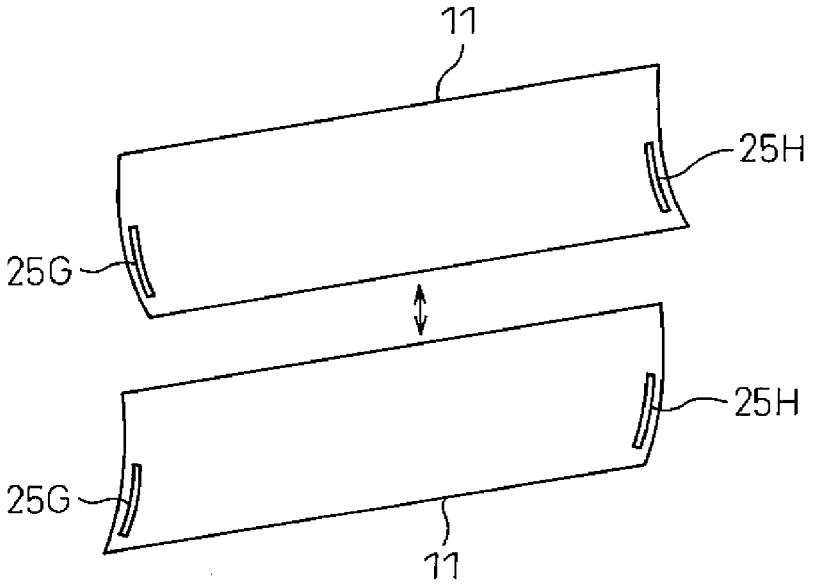


FIG.4

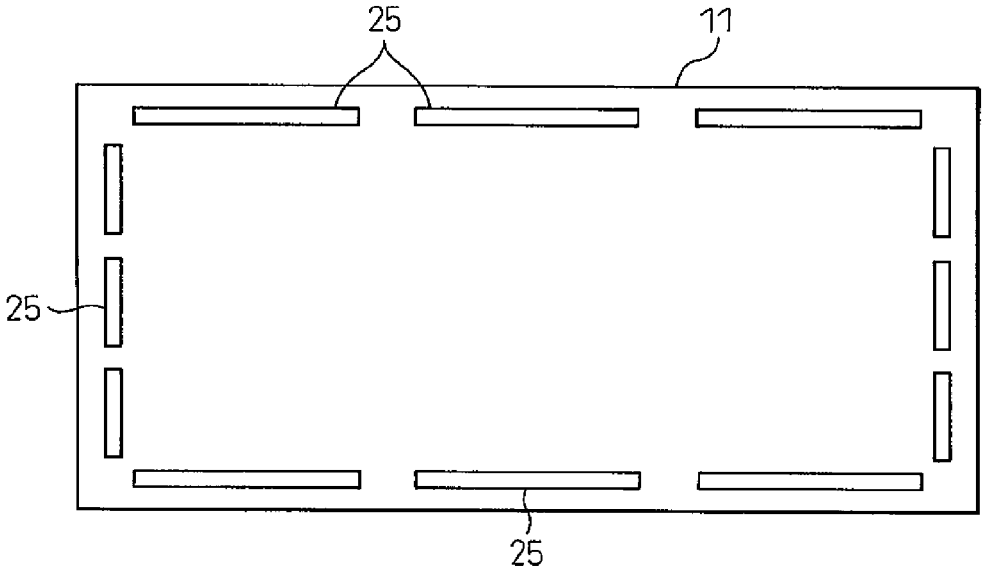


FIG.5

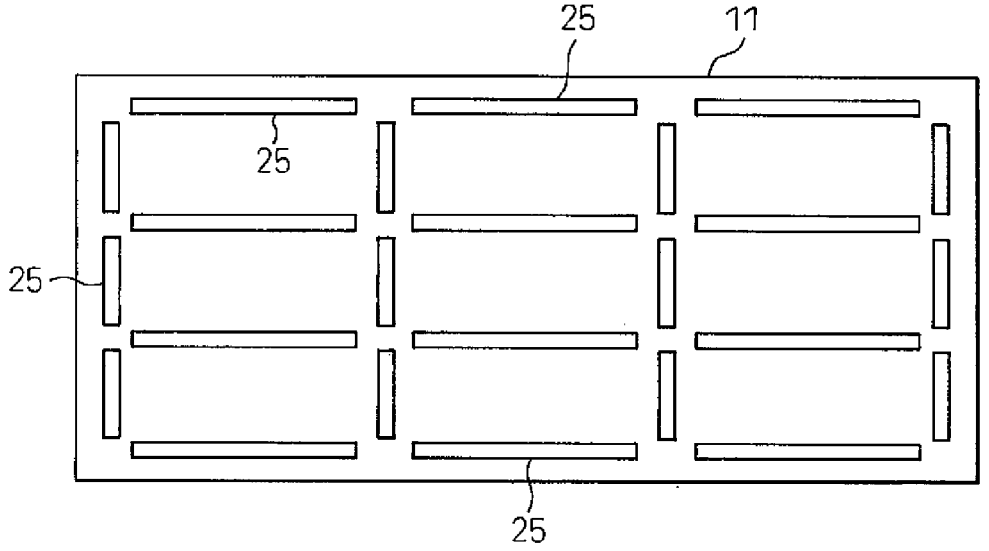


FIG.6A

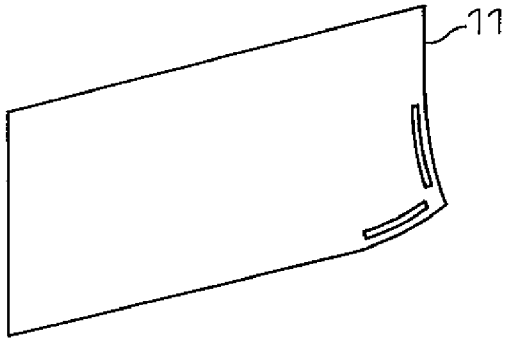


FIG.6B

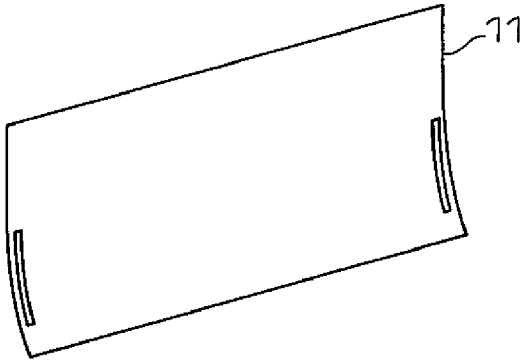


FIG.6C

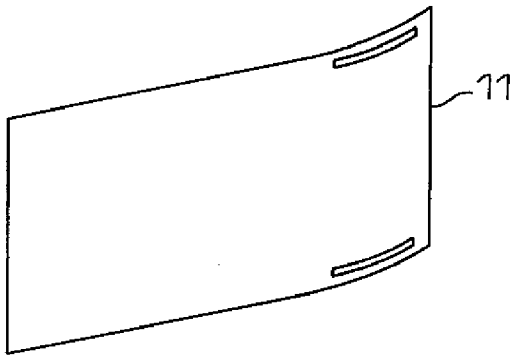


FIG.6D

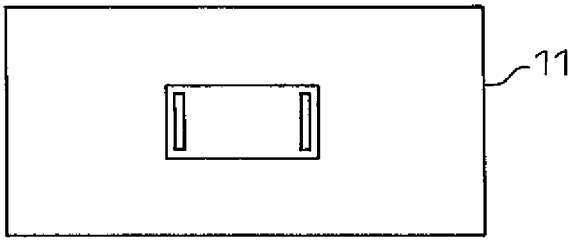


FIG.6E

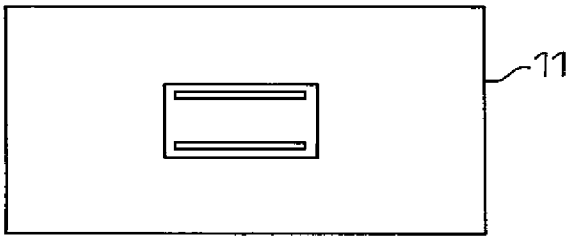


FIG.6F

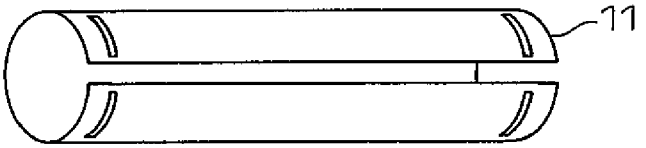


FIG.6G

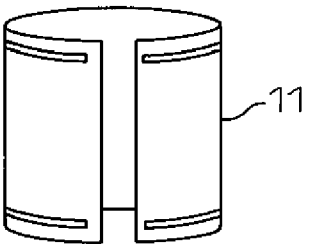


FIG.7A

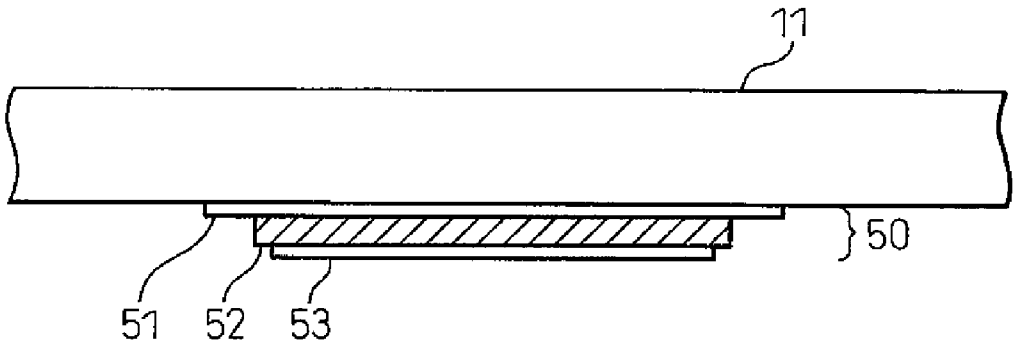


FIG.7B

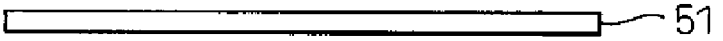


FIG.7C

FIG.8A

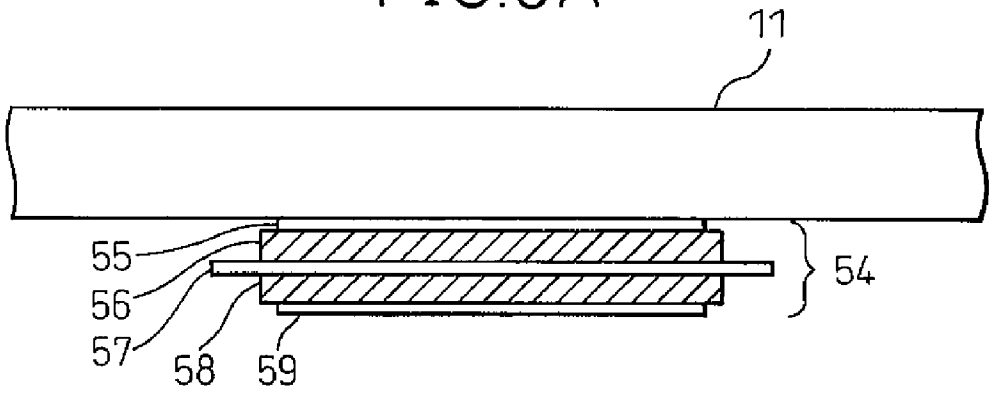


FIG.8B

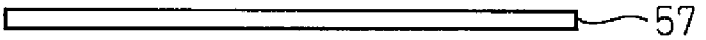


FIG.8C

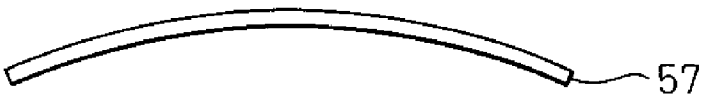


FIG.8D

FIG.9

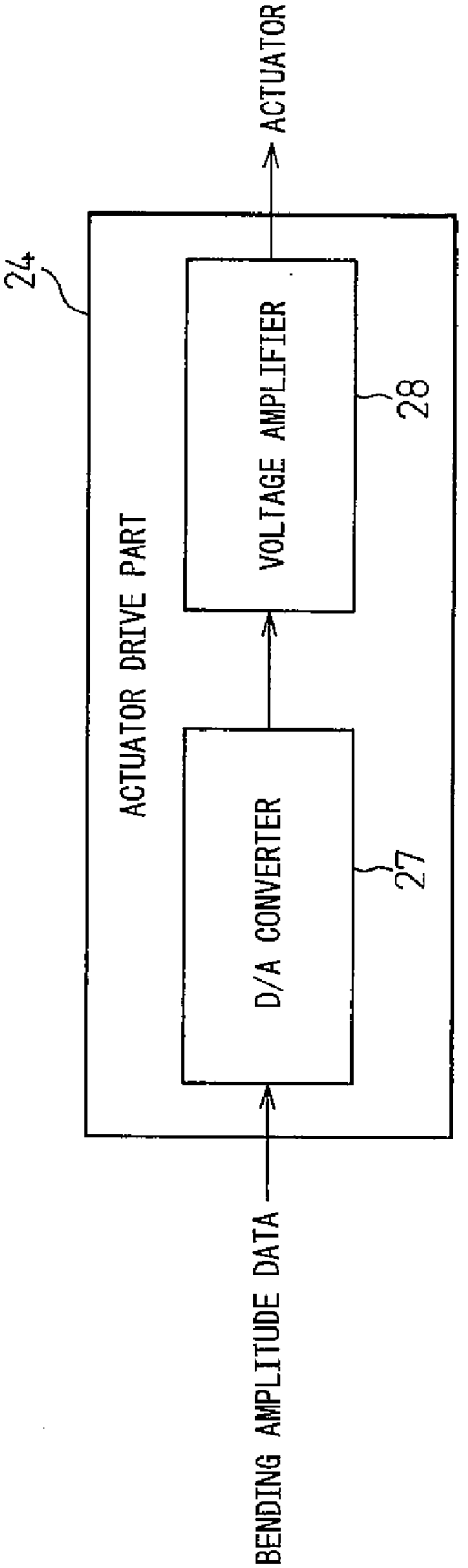

ACTUATOR
24
ACTUATOR DRIVE PART
VOLTAGE AMPLIFIER
28
D/A CONVERTER
27
BENDING AMPLITUDE DATA

FIG.10A

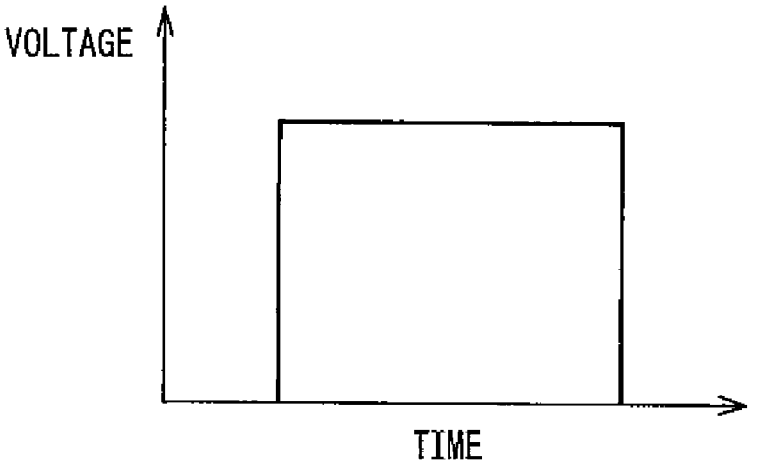


FIG.10B

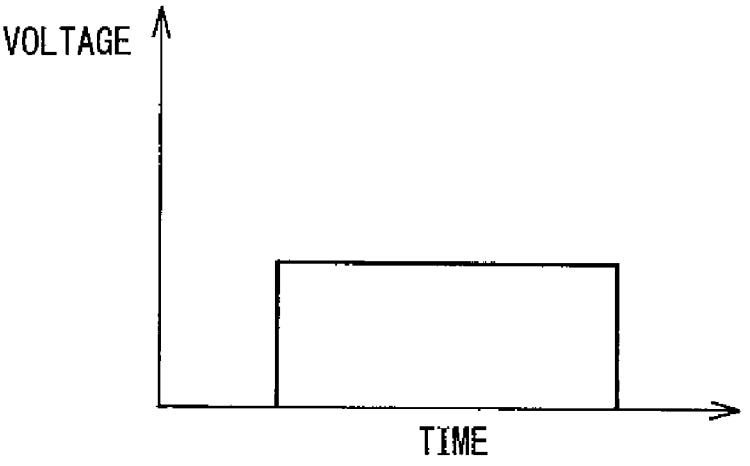


FIG.10C

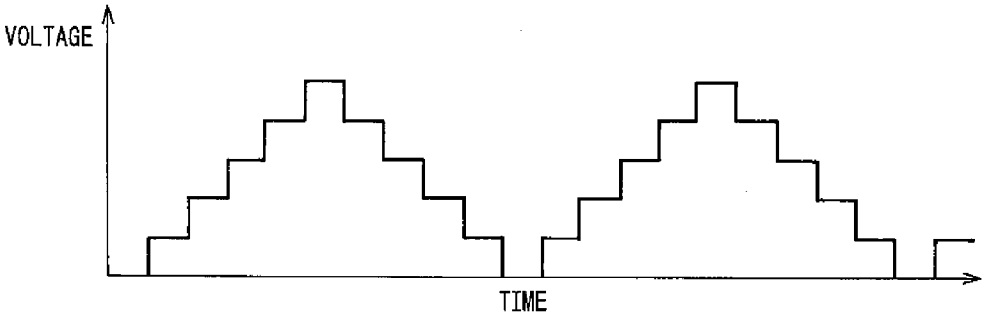


FIG.10D

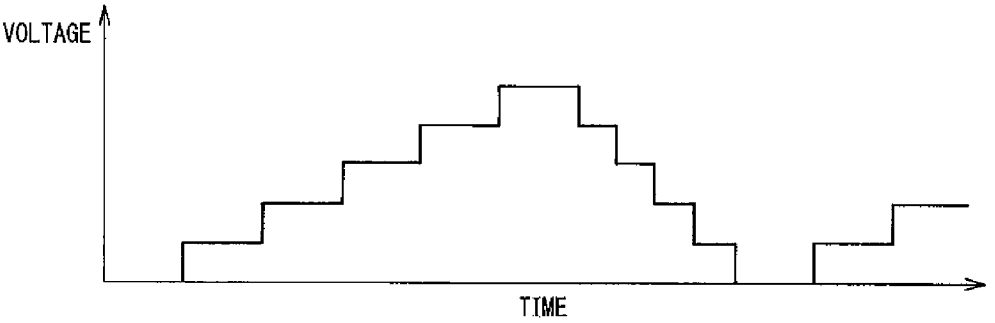


FIG.11A

FIG.11B

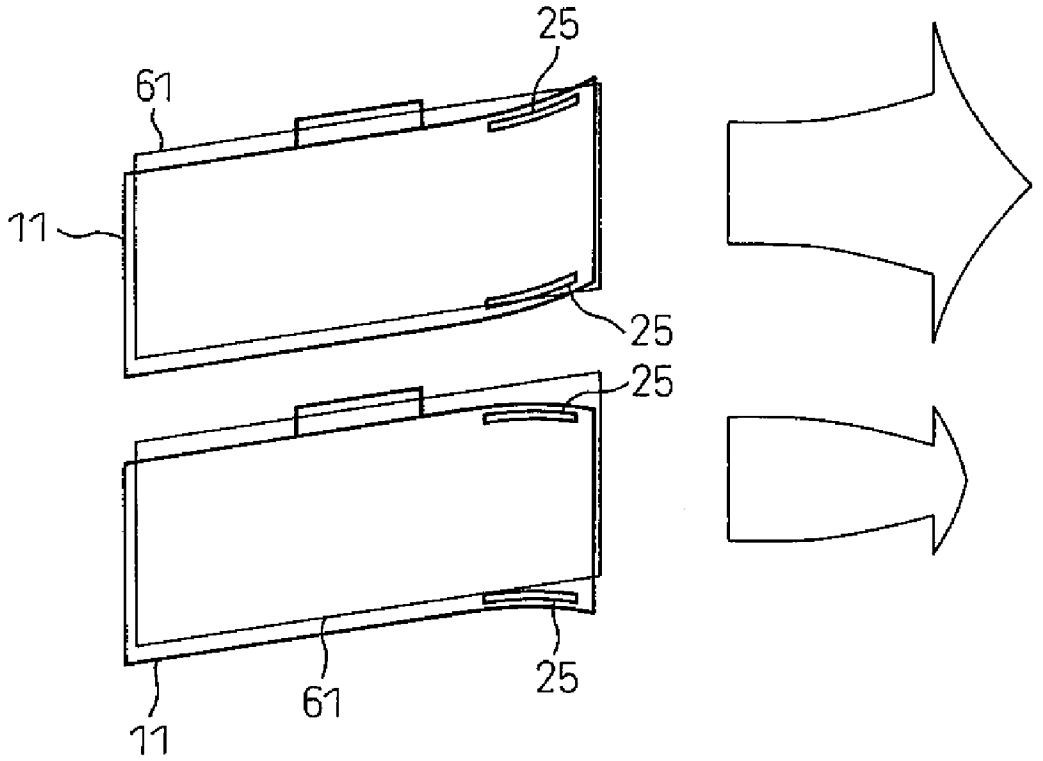


FIG.12

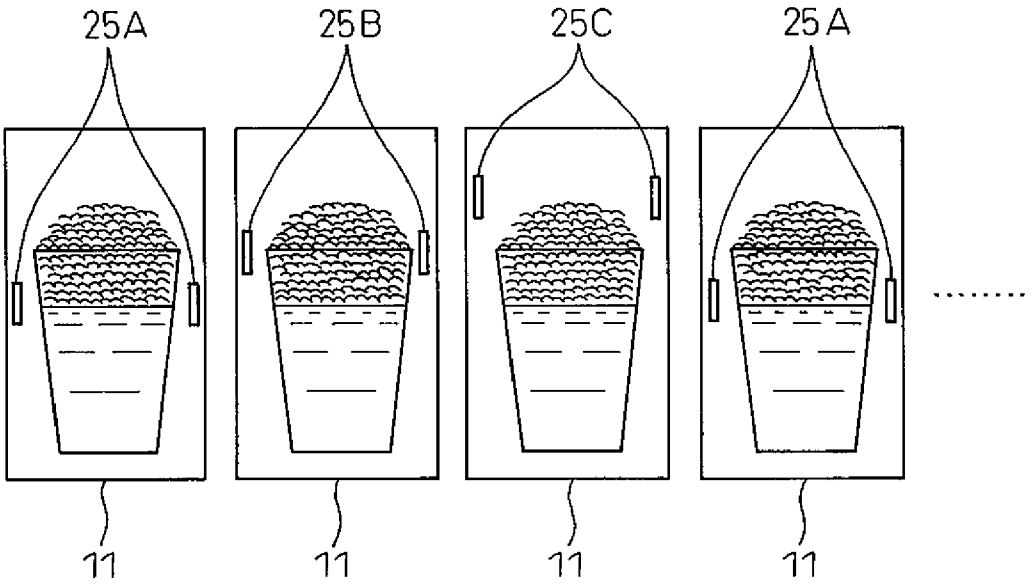


FIG.13A

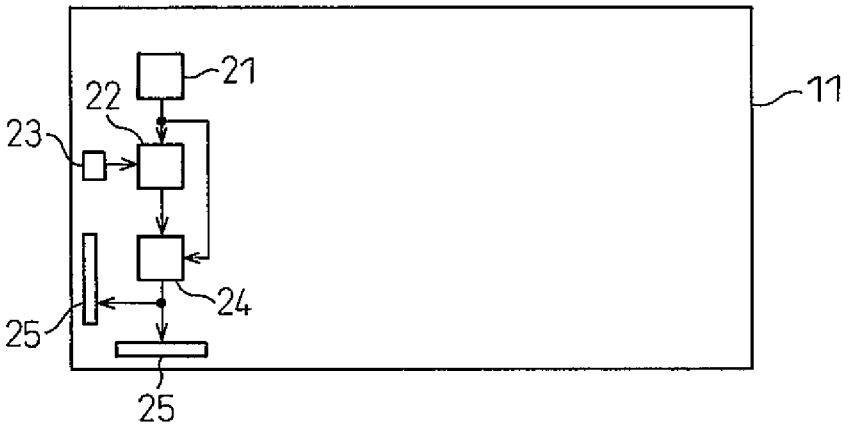


FIG.13B

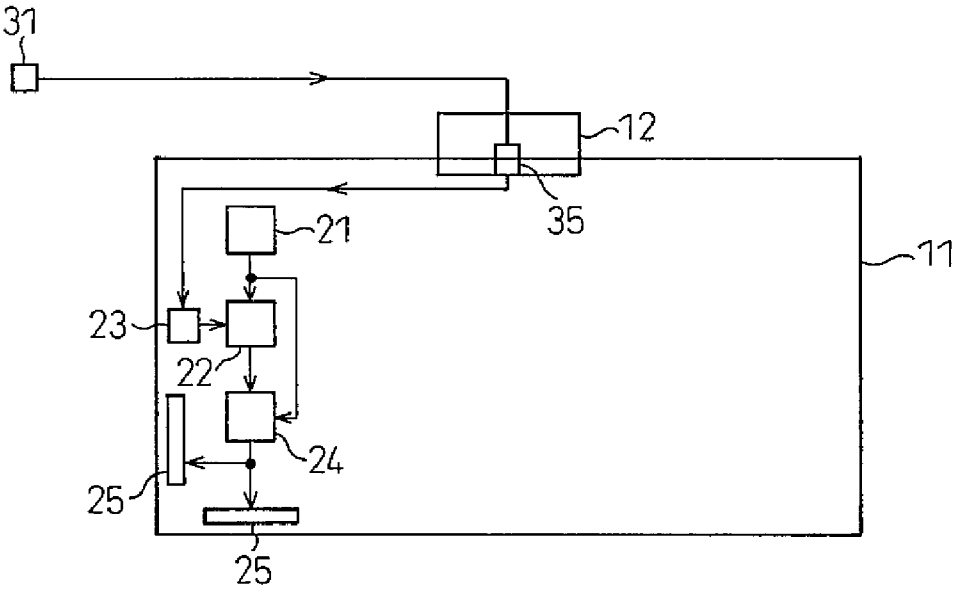


FIG.13C

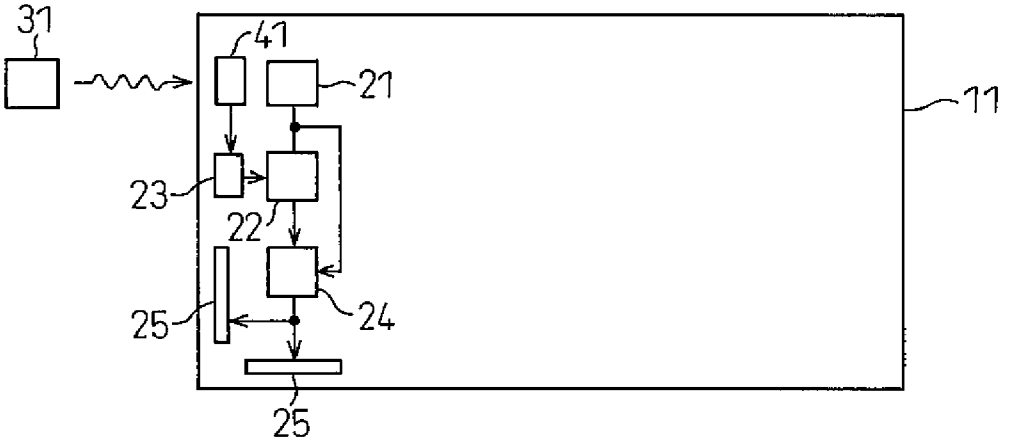


FIG.14A

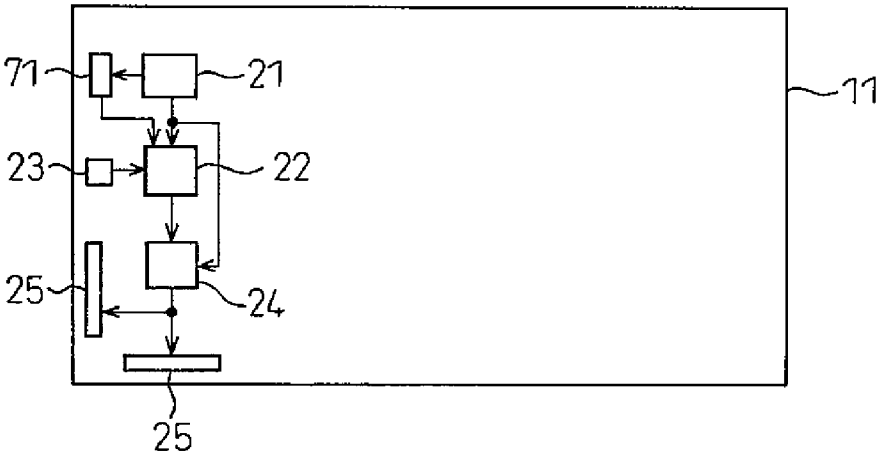


FIG.14B

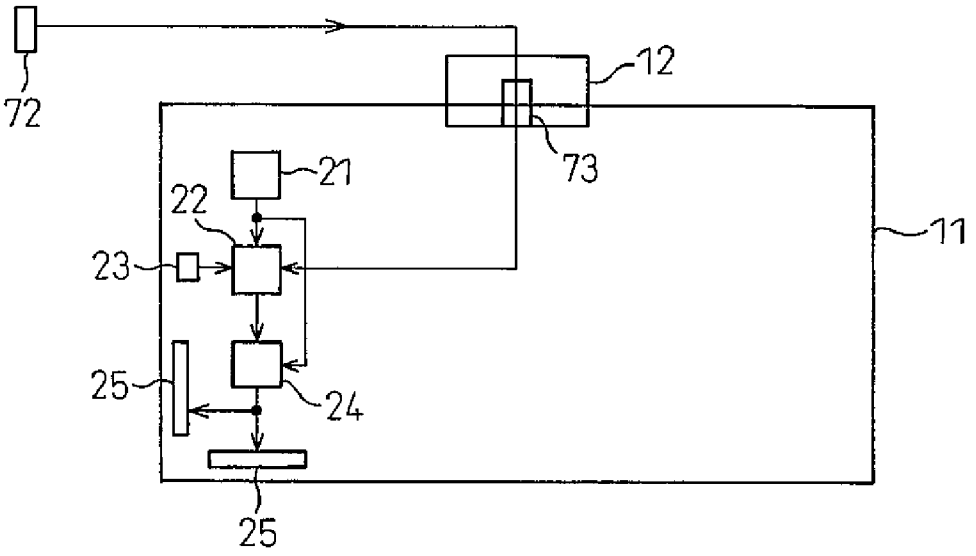


FIG.14C

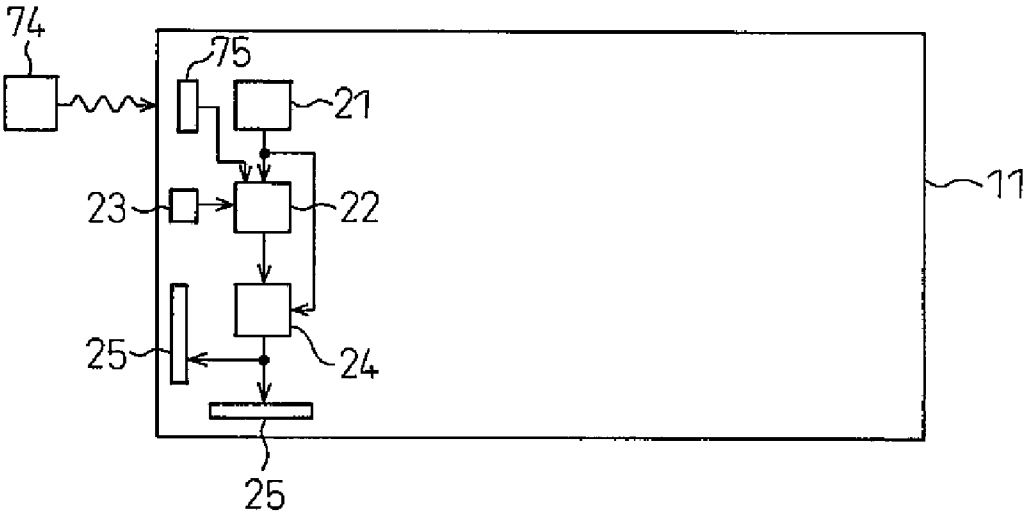


FIG.15A

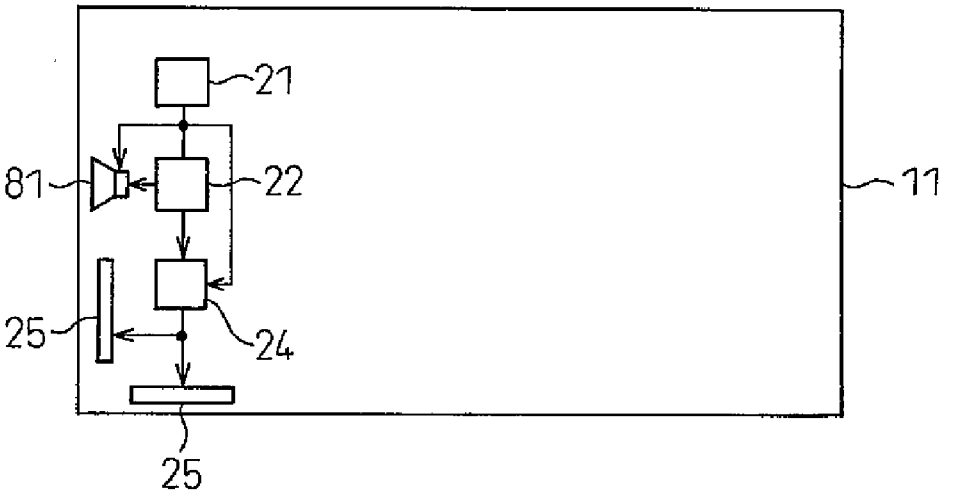


FIG.15B

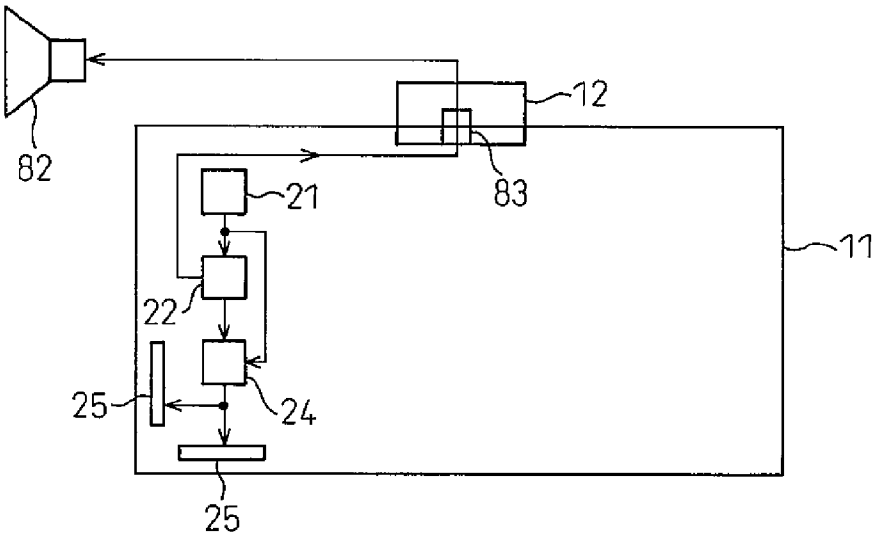


FIG.15C

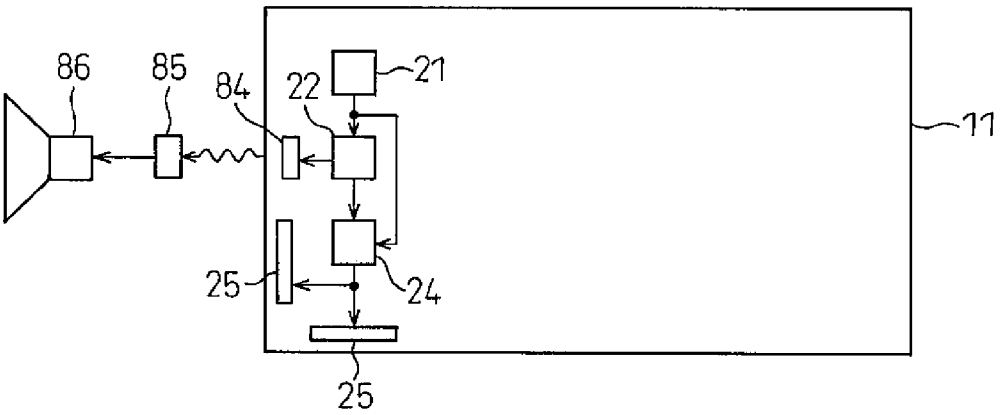


FIG.16

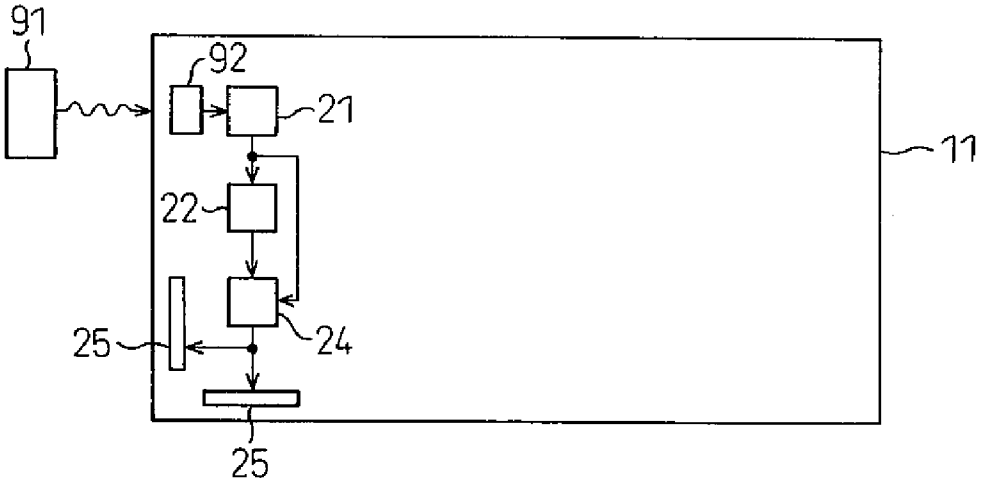


FIG.17

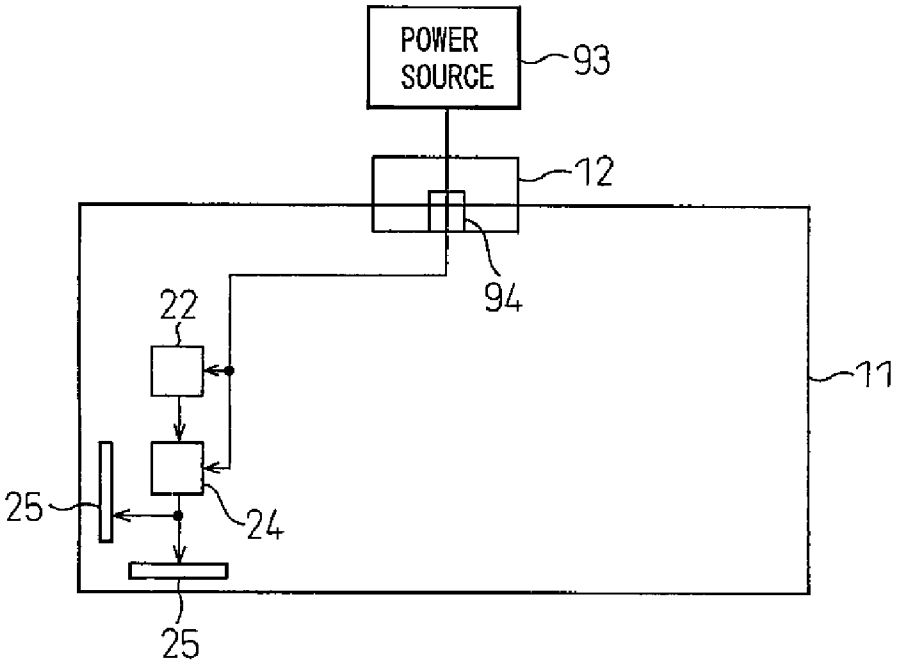
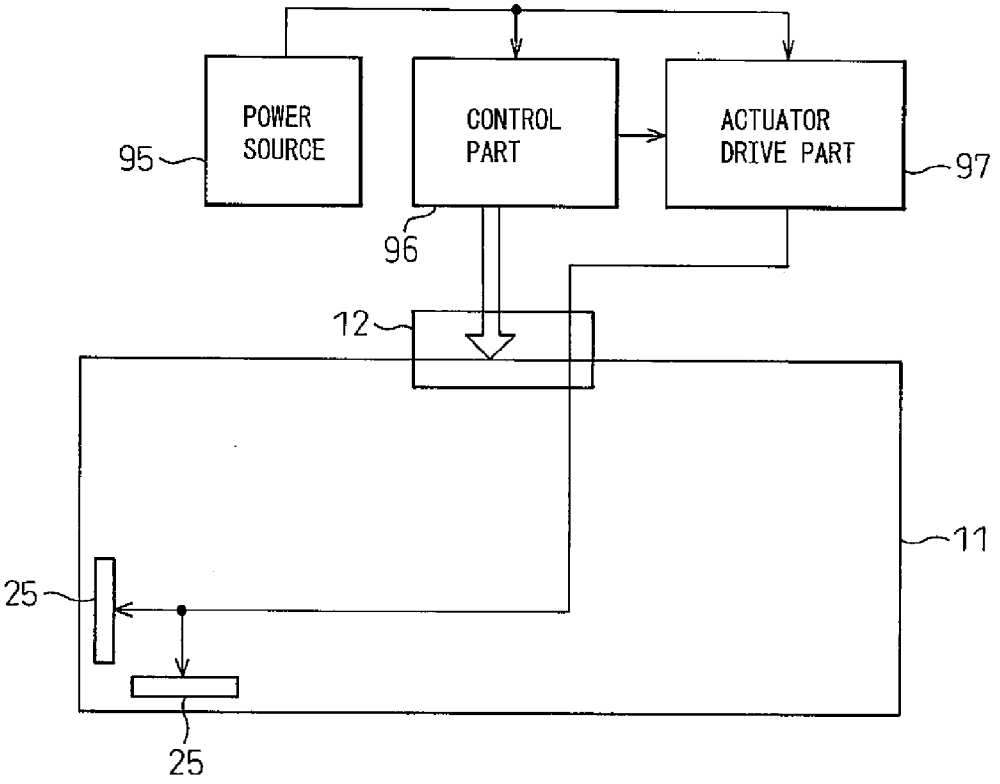


FIG.18


POWER SOURCE
CONTROL PART
ACTUATOR DRIVE PART
95
96
97
12
11
25
25

DISPLAY DEVICE AND DISPLAY SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation application and is based upon PCT/JP2007/070363, filed on Oct. 18, 2007, the entire contents of which are incorporated herein by reference.

FIELD

[0002] The embodiments discussed herein are related to a display device and a display system including a flexible display element, such as flexible electronic paper, and in particular, to a display device and a display system including a display element capable of being bent.

BACKGROUND

[0003] On paper, as an advertising/display medium, advertising content and display content are printed in advance, and therefore, the advertising content and the display content cannot be changed. When the advertising content and display content has ended, the paper on which the advertising content and display content are printed is discarded.

[0004] In recent years, a flexible display element, such as electronic paper that is thin and flexible and in which display content can be rewritten, has been developed. It is possible to increase the degree of attention compared to the case where conventional paper is used by displaying the advertising content on such a flexible display element instead of posting up paper on which the advertising content and the display content are printed in advance and by rewriting an image in accordance with the change in circumstances.

[0005] Japanese Laid-open Patent Publication No. 2003-114635 describes a paper-like information display medium that is thin and flexible and an information providing method and an information providing system using the same, and also describes a configuration that provides information timely and meticulously by distributing information data while "taking time and place into consideration" onto the information display, as an advertisement hanging from the ceiling of a train or bus.

[0006] International Publication Pamphlet No. WO2005/024774 describes a method of supplying data and electric power to an information display medium.

[0007] Japanese Laid-open Patent Publication No. 2003-280546 describes an information display element capable of being bent into a predetermined shape by providing an actuator to an information display element that is thin and flexible.

SUMMARY

[0008] According to an aspect of the embodiments, a display device includes: a display part that displays an image; and a control part that causes the display part to bend in accordance with the display image.

[0009] The object and advantages of the embodiments will be realized and attained by means of the elements and combination particularly pointed out in the claims.

[0010] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1**A is a diagram illustrating a configuration of a display system in an embodiment;

[0012] FIG. **1**B is a diagram explaining a bending motion of a display device in the embodiment;

[0013] FIG. **1**C is a block diagram illustrating a functional configuration of the display system;

[0014] FIG. **2** is a diagram explaining a modified example of a bending motion of the display device;

[0015] FIG. **3** is a diagram explaining a modified example of a bending motion of the display device;

[0016] FIG. **4** is a diagram explaining a modified example of an arrangement of actuators of the display device;

[0017] FIG. **5** is a diagram explaining a modified example of an arrangement of actuators of the display device;

[0018] FIG. **6**A is a diagram explaining an example of a bending motion that can be realized by the arrangement of the actuators in FIG. **4** and FIG. **5**;

[0019] FIG. **6**B is a diagram explaining an example of a bending motion that can be realized by the arrangement of the actuators in FIG. **4** and FIG. **5**;

[0020] FIG. **6**C is a diagram explaining an example of a bending motion that can be realized by the arrangement of the actuators in FIG. **4** and FIG. **5**;

[0021] FIG. **6**D is a diagram explaining an example of a bending motion that can be realized by the arrangement of the actuators in FIG. **4** and FIG. **5**;

[0022] FIG. **6**E is a diagram explaining an example of a bending motion that can be realized by the arrangement of the actuators in FIG. **4** and FIG. **5**;

[0023] FIG. **6**F is a diagram explaining an example of a bending motion that can be realized by the arrangement of the actuators in FIG. **4** and FIG. **5**;

[0024] FIG. **6**G is a diagram explaining an example of a bending motion that can be realized by the arrangement of the actuators in FIG. **4** and FIG. **5**;

[0025] FIG. **7**A is a diagram illustrating a structure of a piezoelectric actuator including a monomorph structure;

[0026] FIG. **7**B is a diagram illustrating a bent state of a piezoelectric actuator including the monomorph structure;

[0027] FIG. **7**C is a diagram illustrating a bent state of a piezoelectric actuator including the monomorph structure;

[0028] FIG. **8**A is a diagram illustrating a structure of a piezoelectric actuator including a bimorph structure;

[0029] FIG. **8**B is a diagram illustrating a bent state of a piezoelectric actuator including the bimorph structure;

[0030] FIG. **8**C is a diagram illustrating a bent state of a piezoelectric actuator including the bimorph structure;

[0031] FIG. **8**D is a diagram illustrating a bent state of a piezoelectric actuator including the bimorph structure;

[0032] FIG. **9** is a diagram illustrating a configuration of an actuator drive part for making variable an amount of bending of an actuator;

[0033] FIG. **10**A is a diagram illustrating an example of a drive signal of the actuator;

[0034] FIG. **10**B is a diagram illustrating an example of a drive signal of an actuator;

[0035] FIG. **10**C is a diagram illustrating an example of a drive signal of the actuator;

[0036] FIG. **10**D is a diagram illustrating an example of a drive signal of the actuator;

[0037] FIG. **11**A is a diagram illustrating an example of a display image in a modified example in which a Fresnel lens is arranged on the front surface of a display device;

[0038] FIG. **11**B is a diagram illustrating a modified example in which a Fresnel lens is arranged on the front surface of a display device;

[0039] FIG. **12** is a diagram explaining a modified example in which an actuator that bends in accordance with a display image is changed;

[0040] FIG. **13**A is a diagram illustrating a configuration of a display device in which data is stored in a storage part in an off-line manner;

[0041] FIG. **13**B is a diagram illustrating a configuration of a display device in which data is transmitted from an external transmission part to a storage part via a wired interface of a holding part;

[0042] FIG. **13**C is a diagram illustrating a configuration of a display device in which data is transmitted from an external transmission part to a storage part via a wireless interface;

[0043] FIG. **14**A is a diagram illustrating a configuration in which a sensor is provided in a display device;

[0044] FIG. **14**B is a diagram illustrating a configuration of a display device in which a sensor is provided externally and a sensor detection signal is transmitted to a control part via a wired interface of a holding part;

[0045] FIG. **14**C is a diagram illustrating a configuration of a display device in which a sensor is provided externally and a sensor detection signal is transmitted to a control part via a wireless interface;

[0046] FIG. **15**A is a diagram illustrating a configuration in which a speaker is provided in a display device;

[0047] FIG. **15**B is a diagram illustrating a configuration in which a speaker is provided externally and a voice stream is transmitted from a control part to the speaker via a wired interface of a holding part;

[0048] FIG. **15**C is a diagram illustrating a configuration in which a speaker is provided externally and a voice stream is transmitted from a control part to the speaker via a wireless interface;

[0049] FIG. **16** is a diagram illustrating a configuration in which electric power is supplied to a power source of a display device by a high frequency wireless signal for electric power;

[0050] FIG. **17** is a diagram illustrating a configuration in which a power source is provided externally and electric power is supplied to a display device via a wired interface of a holding part;

[0051] FIG. **18** is a diagram illustrating a configuration in which a power source, a control part, and an actuator drive part are provided externally and an image rewrite signal and an actuator drive signal are supplied to a display part via a wired interface of a holding part.

DESCRIPTION OF EMBODIMENTS

[0052] Embodiments are explained below with reference to the drawings.

[0053] FIG. **1**A is a diagram illustrating a configuration of a display system in an embodiment.

[0054] As illustrated in FIG. **1**A, the display system in the embodiment includes a display device **10** and a transmission part **31**. The display device **10** includes a flexible display element **11** including a display screen **13**, a thin power source **21**, a display control part **22**, a storage part **23** that stores image data and data of bending motion corresponding to the image data, an actuator drive part **24**, and actuators **25**A to **25**D. As will be described later, the display device **10** also includes a display drive part that drives the flexible display element **11**, however, it is not illustrated schematically here. This also applies in other drawings. The thin power source **21**, the display control part **22**, the storage part **23**, the actuator drive part **24** and the actuators **25**A to **25**D are provided on the flexible display element **11**.

[0055] The transmission part **31** transmits image data and data of bending motion corresponding to the image data to the display device **10**. The image data and data of bending motion transmitted from the transmission part **31** are stored in the storage part **23**.

[0056] The data of bending motion includes data about a number for identifying an actuator(s) when a plurality of actuators are provided, a bending mode that specifies the type of bending motion, timing of bending motion, etc.

[0057] As the flexible display element **11**, it is also possible to use a thin liquid crystal display or EL display, however, electronic paper that does not require electric power, except when rewriting, is preferable when the frequency of rewriting is low, such as in an advertising display. In particular, a cholesteric liquid crystal color electronic paper that is light in weight and capable of a bright color display is most preferable. The cholesteric liquid crystal display device is widely known and described in, for example, patent document 2, and therefore, its detailed explanation is omitted here.

[0058] Either way, the flexible display element **11** has flexibility, i.e., the flexible display element **11** is flexible and desirable to be in the form of a sheet. In the following explanation, it is assumed that the flexible display element **11** is electronic paper.

[0059] The display control part **22** reads image data and data of bending motion stored in the storage part **23**, selects a kind of image, and displays the image on the flexible display element (electronic paper) **11** at a display timing associated with the image and at the same time, controlling the actuator drive part **24** in accordance with the data of bending motion associated with the image. In response to this, the actuator drive part **24** drives the actuators **25**A to **25**D. The power source **21** supplies electric power to each component.

[0060] The power source **21**, the display control part **22**, the storage part **23** and the actuator drive part **24** are light and thin and provided on the backside of the flexible display element **11**. The display drive part, not illustrated schematically, is also light and thin and provided on the backside of the flexible display element **11**.

[0061] As the actuators **25**A to **25**D, it is also possible to use those of normal electromagnetic type and provide separately from the flexible display element **11**, however, an actuator in the form of a sheet is preferable and provided on the backside of the flexible display element **11**. It is possible to realize a display and bending features of the flexible display element **11** while allowing the flexible display element **11** to remain in the form of a thin sheet by using an actuator in the form of a strip.

[0062] FIG. **1**B is a diagram explaining the bending motion of the flexible display element **11**. Reference numeral **12** represents a holding member for holding the flexible display element **11**. The flexible display element **11** includes the four actuators **25**A to **25**D provided along the upper and lower edges, and therefore, the right and left sides are bent by

driving them. Due to this, for example, it is possible to bring the flexible display element **11** into a wavy state as illustrated in FIG. **1**B. Further, it is also be possible to bend the display element so as to form part of a cylinder. Furthermore, it is possible to cause the display element to perform a wavy motion by repeating turning on/off of the bending motion, and the degree of attention can be changed by changing the speed of the bending motion.

[0063] FIG. **10** is a block diagram illustrating a functional configuration of a display system in the embodiment. As illustrated in FIG. **10**, the transmission part **31** includes a transmission data storage part **32** that stores image data and data of bending motion corresponding to the image data, and a data transmission part **33** that transmits the image data and data of bending motion read from the transmission data storage part **32** to the display device **10**.

[0064] Reference numeral **34** represents a transmission path of image data and data of bending motion. As will be described later, there can be various modifications for the transmission path **34**.

[0065] The display device **10** includes a reception part **41** that receives image data and data of bending motion transmitted from the transmission part **31**, the storage part **23** that stores the received image data and data of bending motion, the display control part **22**, the actuator drive part **24**, the actuator **25** (**25**A to **25**D), a display drive part **26**, the flexible display element **11**, and the power source **21**.

[0066] To the part in relation to the image display of the part configured by the transmission data storage part **32**, the data transmission part **33**, the transmission path **34**, the power source **21**, the reception part **41**, the storage part **23**, the display control part **22**, the display drive part **26**, and the display part **13**, the conventional configuration described in, for example, patent document 2, can be applied as it is. The present embodiment differs from the conventional example in that the transmission data storage part **32**, the data transmission part **33**, the transmission path **34**, the reception part **41**, the storage part **23**, and the display control part **22** deal with data of bending motion and in that the actuator drive part **24** and the actuator **25** are provided.

[0067] FIG. **2** and FIG. **3** are diagrams each illustrating a modified example of positions at which actuators are provided.

[0068] In FIG. **2**, actuators **25**E and **25**F in the form of a strip are provided, respectively, on the vertical side and the bottom side near one corner of the flexible display element **11**. By driving the actuators **25**E and **25**F, the one corner on the bottom side bends and the flexible display element **11** is brought into a state where the corner is turned up or turned down.

[0069] When the flexible display element **11** illustrated in FIG. **2** is used for advertisement, it is possible to increase the degree of attention and further magnify the advertising effectiveness by displaying a brand name, advertising phrase, sponsor name, etc., at the corner part of the flexible display element **11** at which the actuators **25**E and **25**F are provided.

[0070] By continuously repeating the bending motion, the one corner on the bottom side rocks back and forth. By repeating the bending motion at high speed, the corner will attract attention in a manner different from that when the bending motion is repeated at low speed.

[0071] In FIG. **3**, actuators **25**G and **25**H in the form of a strip are provided in parallel with each other on both vertical sides of the flexible display element **11**. By driving both the actuators **25**G and **25**H at the same time, the flexible display element **11** bends so as to be a part of a cylinder. If this bending motion is performed continuously, the bottom side rocks back and forth.

[0072] As illustrated in FIG. **4** and FIG. **5**, it is also possible to provide more actuators **25** on the flexible display element **11**. In the example in FIG. **4**, the actuators **25** are provided along the four sides of the flexible display element **11** and all of the bending motions in FIG. **1**B, FIG. **2** and FIG. **3** can be realized by selecting and driving the two or more actuators **25**.

[0073] In the example in FIG. **5**, the plurality of the actuators **25** are provided on the flexible display element **11** in the form of a grid. FIG. **6**A to FIG. **6**G show examples of the bending motions that can be realized by the arrangement of the actuators **25** in FIG. **5**. In FIG. **6**A to FIG. **6**G, only the actuators that are driven are illustrated. FIG. **6**D and FIG. **6**E show the bending of the flexible display element **11** in FIG. **6**B and FIG. **6**C localized only in a part. In particular, if the bending is such as illustrated in FIG. **6**F and FIG. **6**G, it is possible to greatly impact the advertisement of canned beverages, etc.

[0074] Various bending states, in addition to those examples illustrated in FIG. **6**A to FIG. **6**G, can be realized by combining the actuators **25** to be bent. Further, when an actuator, the bending direction of which can be selected is used, it is possible to select a bending direction, and therefore, to realize even more bending states. No more explanation on the bending state is given here.

[0075] Next, an actuator in the form of a sheet is explained. As described above, when the present embodiment is realized, it is preferable to use an actuator in the form of a thin sheet. As an actuator in the form of a sheet having high utility, mention is made of, for example, a piezoelectric actuator including a monomorph/bimorph structure widely known as a piezoelectric element. Further, there is a thermal distortion actuator including a monomorph/bimorph structure, and an actuator can be used, which has a thickness of about 25 μm and capable of bending cholesteric liquid crystal color electric paper having a thickness of 300 μm, however, an piezoelectric actuator is more desirable from the standpoint of power consumption.

[0076] FIG. **7**A is a diagram illustrating a structure of an actuator **50** including a monomorph structure that uses a plate-shaped piezoelectric element and FIG. **7**B and FIG. **7**C show its bent states.

[0077] As illustrated in FIG. **7**A, the actuator **50** including a monomorph structure includes a lower electrode **51**, a plate-shaped piezoelectric element **52** provided on the lower electrode **51**, and an upper electrode **53** provided on the plate-shaped piezoelectric element **52**, and is attached to the backside of the electronic paper **11** by the adhesion of the lower electrode **51** thereto. The thickness of the flexible display element (electronic paper) **11** is 300 μm, the thickness of a stainless plate constituting the upper electrode is 25 μm, and the thickness of the plate-shaped piezoelectric element **52** is 50 μm. A piezoelectric constant d**31** is −300 pm/V and a piezoelectric applied voltage is 60 V. When a voltage of 60 V is applied, the electric field strength is 1.2 kV/mm and the stainless plate constituting the upper electrode bends at a radius of curvature of about 1 m, and in response to this, the electronic paper **11** also bends. FIG. **7**B shows a state where no voltage is applied and the stainless plate constituting the upper electrode **51** is in a flat state. Because this actuator includes a monomorph structure, the direction of bending is

only toward one side and when a voltage is applied, the stainless plate constituting the upper electrode **51** bends so as to form a convex shape, as illustrated in FIG. **7**C.

[0078] FIG. **8**A is a diagram illustrating a structure of an actuator **54** including a bimorph structure that uses a plate-shaped piezoelectric element and FIG. **8**B to FIG. **8**D show its bent states.

[0079] As illustrated in FIG. **8**A, the actuator **54** including a bimorph structure includes a common electrode **57** made of a stainless plate, a lower side plate-shaped piezoelectric element **56** provided on one side of the common electrode **57**, an upper side plate-shaped piezoelectric element **58** provided on the other side of the common electrode **57**, the lower electrode **51** provided on the lower side plate-shaped piezoelectric element **56**, and an upper electrode **59** provided on the upper side plate-shaped piezoelectric element **58**, and is attached to the backside of the electronic paper **11** by the adhesion of a lower electrode **55** etc. The thickness of the electronic paper **11** is 100 μm, the thickness of the stainless plate constituting the common electrode **57** is 25 μm, and the thickness of the lower side and upper side plate-shaped piezoelectric elements **56**, **58** is 50 μm. The piezoelectric constant d**31** is −300 pm/V and the piezoelectric applied voltage is 60 V. When a voltage of 60 V is applied, the stainless plate constituting the common electrode bends at a radius of curvature of about 1 m, and in response to this, the electronic paper **11** also bends. FIG. **8**B shows a state where no voltage is applied and the stainless plate constituting the upper electrode **51** is in a flat state. Because this actuator includes a bimorph structure, it can bend to both sides and when a voltage is applied to the upper electrode **59**, the upper electrode **59** bends so as to form a concave shape as illustrated in FIG. **8**C and when a voltage is applied to the lower electrode **55**, the upper electrode **59** bends so as to form a convex shape as illustrated in FIG. **8**D.

[0080] If a piezoelectric element having excellent crystallinity, which is manufactured by the sol-gel method or RF sputtering method, is used as the plate-shaped piezoelectric elements **52**, **56**, **58** in the actuator **50** including a monomorph structure in FIG. **7**A and the actuator **54** including a bimorph structure in FIG. **8**A, the electric field strength is 18 kV/mm and the stainless plate bends at a radius of curvature of about 10 cm when a voltage of 900 V is applied, and therefore, it is possible to considerably bend the electronic paper **11** having a thickness of 300 μm.

[0081] When only the bending (on/off) of a plate-shaped piezoelectric element is controlled, complicated waveforms are not necessary to drive it, and it is only required to simply turn on/off a predetermined voltage using a drive transistor etc. provided in the actuator drive part **24**. The drive power source of a display medium is about 30 V, for example, in the case of cholesteric liquid crystal, and if the voltage required to drive the actuator is about 60 V, it is possible to easily generate waves only by adding a publicly known voltage doubler output circuit to the drive power source of the display medium. When the above-mentioned piezoelectric element excellent in crystallinity is used and is considerably bent by applying a voltage of 900 V, it is necessary to provide a high voltage power source exclusive for the piezoelectric element.

[0082] It is also possible to control (1) the amount of bending and (2) the speed of bending of the plate-shaped piezoelectric element, in addition to only the bending (on/off), and in such a case, the amplitude of a voltage to be applied to the plate-shaped piezoelectric element and the rate of change in speed are controlled.

[0083] FIG. **9** is a diagram illustrating the configuration of the actuator drive part **24** when the amount of bending and the speed of bending are controlled. As illustrated in FIG. **9**, the actuator drive part **24** includes a D/A converter **27** that receives bending amplitude data and issues an analog signal in accordance with the data, and a voltage amplifier **28** that amplifies the D/A converter **27** to generate a voltage to be applied to the actuator.

[0084] FIG. **10**A to FIG. **10**D show voltage waveforms to be applied to the electrode.

[0085] First, a case where (1) how much the element is bent, that is, the amount of bending is controlled is explained with reference to FIG. **10**A and FIG. **10**B. When the power source is turned on, "amplitude=0" is sent to the D/A converter **27** as data of bending motion and the piezoelectric drive voltage becomes 0 V. At this time, the piezoelectric element is in a flat state where it is not bent.

[0086] As illustrated in FIG. **10**A, when the element is bent to the maximum amplitude at a certain timing, "amplitude=1" is sent to the D/A converter **27** as the bending amplitude data and the piezoelectrie drive voltage rapidly changes to the maximum output voltage (for example, 60 V). Due to this, the piezoelectric element is brought into a maximally bent state. While this voltage is being applied, the bent state of the piezoelectric element is maintained. During this period, almost no current flows, and therefore, its power consumption is very small. When the timing at which the state is returned to its original state is reached, "amplitude=0" is sent to the D/A converter **27** as the bending amplitude data and the piezoelectric drive voltage rapidly becomes 0 V, and therefore, the bent state is released and the piezoelectric element enters a flat state.

[0087] As illustrated in FIG. **10**B, when the piezoelectric element is bent to half the maximum amplitude at a certain timing, "amplitude=0.5" is sent to the D/A converter **27** as bending amplitude data and the piezoelectric drive voltage rapidly changes to ½ of the maximum output voltage (for example, 30 V). Due to this, the piezoelectric element is brought into a state of being bent to half the maximum amount of bending and the bent state is maintained while the voltage is being applied. When the timing at which the state is returned to the original state is reached, "amplitude=0" is sent to the D/A converter **27** as bending amplitude data and the piezoelectric drive voltage changes to 0 V, and therefore, the bent state is released and the piezoelectric element is brought into the flat state.

[0088] Next, a case where (2) at which speed the element is bent, i.e., the bending speed is controlled is explained with reference to FIG. **10**C and FIG. **10**D. When the power source is turned on, "amplitude=0" is sent to the D/A converter **27** as data of bending motion and the piezoelectric drive voltage changes to 0 V. At this time, the piezoelectric element is in the flat state where the piezoelectric element is not bent.

[0089] When the piezoelectric element is bent gradually in a predetermined period of time to the maximum amplitude at a certain timing, as illustrated in FIG. **10**C, "amplitude=0.2" is sent to the D/A converter **27** first as bending amplitude data and the piezoelectric drive voltage changes to ⅕ of the maximum output voltage (for example, 12 V). After the voltage is maintained for a period of ⅕ of a predetermined time, "amplitude=0.4" is sent to the D/A converter **27** and the piezoelectric drive voltage changes to ⅖ of the maximum output voltage (for example, 24 V). This is repeated and a predetermined time later, "amplitude=1.0" is sent to the D/A converter **27**

and the piezoelectric drive voltage changes to the maximum output voltage (for example, 60 V). Due to this, the piezoelectric element is brought into the maximally bent state. When the timing at which the state is returned to the original state is reached, "amplitude=0.8" is sent to the D/A converter **27** as bending amplitude data and the piezoelectric drive voltage changes to ⅘ of the maximum output voltage (for example, 48 V). After this voltage is maintained for a period of ⅕ of the predetermined time, "amplitude=0.6" is sent to the D/A converter **27** and the piezoelectric drive voltage changes to ⅗ of the maximum output voltage (for example, 36 V). This is repeated and a predetermined time later, "amplitude=0" is sent to the D/A converter **27** and the piezoelectric drive voltage changes to 0 V, and therefore, the bent state is released and the piezoelectric element is brought into the flat state.

[0090] FIG. **10**D shows a case where the piezoelectric drive voltage is changed to the maximum output voltage in double the time compared to the case in FIG. **10**C, however, the voltage is changed from the maximum output voltage to 0 V in half the time (the same period of time as that in FIG. **10**C).

[0091] There can be various modified examples for the control of the amount of bending and the bending speed. For example, when the bending speed is changed, control in which the amount of bending per step and the total amount of bending are changed, control in which one of the changes is such that the output voltage is changed rapidly to the final voltage as illustrated in FIG. **10**A and FIG. **10**B, etc., are possible.

[0092] Next, a modified example to further magnify the effect of display by bending is explained.

[0093] FIG. **11**A and FIG. **11**B are diagrams illustrating a configuration of a display system in a modified example. In this display system, by using a Fresnel lens **61** also in the display element device (electronic paper **13**) **11**, the visual change of a display image is enlarged optically.

[0094] As illustrated in FIG. **11**B, the actuators **25** are provided along the upper side and the lower side near one of the ends of the flexible display element (electronic paper) **11** and the one of the sides of the flexible display element **11** can be bent to both sides. When this side part is bent, the distance between the display surface and the Fresnel lens **61** changes, and therefore, the expansion ratio of the displayed image changes considerably.

[0095] For example, in the case where a public sign, such as "EXIT" as illustrated in FIG. **11**A, is displayed on the flexible display element **11**, if an arrow indicating the direction of the exit is displayed at the side part, the size of the arrow is increased and decreased as illustrated in FIG. **11**B, and thereby, the degree of attention is increased considerably.

[0096] In the example illustrated in FIG. **11**A and FIG. **11**B, by bending the part of the arrow indicating the exit, the appearance of the arrow, which is the most important target of attention, is changed (size is increased and decreased), and thus, the degree of attention is increased. In order to perform this motion of the flexible display element **11** including the actuators illustrated in FIG. **4** and FIG. **5**, the positional information of the arrow part, as the position to be bent, and information about a bent shape (cylindrical shape the axis of which is parallel with the side), as the way it is bent, for example, information concerning turning on/off of bending at two-second intervals (in the case of an actuator including a bimorph structure, the reversal of the bending direction), as a bending timing, are associated with the display image and stored in the storage part **23**. Conversion from these pieces of information into drive conditions of each actuator is performed by referring to a lookup table for conversion or by utilizing a conversion program of a microcomputer constituting the control part.

[0097] When an advertisement is displayed instead of a public sign, if a brand name, advertising phrase, or sponsor name, etc., is displayed at the part of the arrow in FIG. **11**A, it is possible to obtain a high degree of advertising effectiveness.

[0098] If a display device capable of displaying a motion picture is used, it is possible to obtain the same effect by changing the size of the arrow to be displayed, however, because a motion picture is displayed, energy to be consumed is by far greater compared to the example illustrated in FIG. **11**B, and therefore, not practical. Further, when a motion picture is displayed, if the speed of drawing is not sufficiently high, there arises a problem of flickering etc. in the display. According to the present embodiment, such a problem will not arise.

[0099] FIG. **12** shows an example to increase the degree of advertising effectiveness by controlling the positions of the actuators that bend of the flexible display element **11** including the actuators illustrated in FIG. **4** and FIG. **5**, and the timing of bending so as to shift continuously.

[0100] FIG. **12** shows an example of advertisement of beer, in which the part of the froth is bent into a forwardly convex shape. Of the actuators provided along both sides, a set of the actuators that bend changes in order of **25**A, **25**B, and **25**C as illustrated in FIG. **12** and this change is repeated. Due to this, the position at which the actuators bend shifts continuously upward and a visual effect that the froth seems moving is obtained and the degree of attention is increased. This technique is also effective when used in an image of waves that move toward the shore.

[0101] As illustrated in FIG. **1**A, the image data and data of bending motion stored in the storage part **23** are transmitted from the transmission part **31**, however, there can be various transmission systems. FIG. **13**A to FIG. **13**C are diagrams each illustrating an example of a transmission system of the image data and data of bending motion stored in the storage part **23**. In FIG. **13**A and FIG. **13**B, the reception part **41** is omitted.

[0102] FIG. **13**A is a diagram illustrating a configuration of a display device when image data and data of bending motion are transmitted in an offline manner to the storage part **23**. The display device includes a wired interface, not illustrated schematically, receives the image data and data of bending motion from the transmission part **31** via the wired interface, and stores them in the storage part **23**. After the image data and data of bending motion are stored in the storage part **23**, the display device **10** (flexible display element **11**) is installed at a desired position and used. When in use, the state of the wired interface is a disconnected state, and therefore, it is not possible to change the image data and data of bending motion stored in the storage part **23** while the display device **10** is installed.

[0103] FIG. **13**B shows a configuration of a display system in which a wired interface **35** for receiving the image data and data of bending motion to be transmitted from the transmission part **31** to the storage part **23** is provided in the holding member **12** that holds the display device **11**. With this configuration, it is possible to transmit the image data and data of bending motion from the transmission part **31** to the storage

part **23** in a state where the display device **10** (flexible display element **11**) is installed, and to change the image data and data of bending motion stored in the storage part **23** at any time.

[0104] FIG. **13**C shows a configuration of a display system in which image data and data of bending motion are transmitted from the transmission part **31** to the storage part **23** using a wireless interface. The data transmission part **33** of the transmission part **31** is a wireless transmission part and outputs image data and data of bending motion as a wireless signal. The reception part **41** of the display device **10** is a wireless reception part and receives a wireless signal of the image data and data of bending motion transmitted from the transmission part **31** and stores it in the storage part **23**. With this configuration also, it is possible to transmit the image data and data of bending motion from the transmission part **31** to the storage part **23** even in a state where the display device **10** (flexible display element **11**) is installed, and to change the image data and data of bending motion stored in the storage part **23** at any time.

[0105] FIG. **14**A to FIG. **14**C are diagrams each illustrating a configuration of a modified example in which the display system in the embodiment is combined with a sensor. In addition to these modified examples, there can be various modified examples according to the position at which a sensor is provided.

[0106] FIG. **14**A is an example in which a sensor **71** is provided in the display device **10** (flexible display element **11**). A detection signal of the sensor **71** is sent to the control part **22**.

[0107] FIG. **14**B is an example in which a sensor **72** is provided in the vicinity of the outside of the display device **10**. A detection signal of the sensor **72** is sent to the control part **22** via a wired interface **73** provided in the holding member **12** that holds the flexible display element **11**.

[0108] FIG. **14**C shows a configuration in which a detection signal is transmitted to the control part **22** from a sensor **74** using a wireless interface. The sensor **74** includes a wireless transmission part that transmits a detection signal in a wireless manner as well as a sensor part. The display device **10** includes a wireless reception part **75** that receives a wireless detection signal and sends the received detection signal to the control part **22**.

[0109] The sensors **71**, **72**, **74** are each sensors that detect, for example, the approach of a passerby. When detecting the approach of a passerby within a predetermined distance from the display device **10** (flexible display element **11**), the sensor outputs a detection signal to the control part **22**. Triggered by this signal, the control part **22** causes the flexible display element **11** to bend as well as suddenly displaying an image on the screen on which nothing is displayed up to that time or changing a display image, and thus, magnifying the advertising effectiveness. When a passerby approaches the display device, an image that is not displayed up to that time is suddenly displayed on the display device or the displayed content changes, and therefore, the probability of attracting attention of the passerby is by far greater compared to an image displayed on paper. Such a display device is arranged along a roadway and the advertising display displayed ahead of a passerby changes sequentially when the passerby moves along the roadway or the advertising display bends in accordance with the movement of the passerby presents a magnificent spectacle, and therefore, the advertising effectiveness is very high.

[0110] In the configuration in FIG. **14**A, because the sensor **71** is provided in the display device **10** (flexible display element **11**), it is required only to arrange the display device **10** (flexible display element **11**) and the holding method is not limited, and therefore, its installation is easy. However, the distance within which the sensor **71** can detect the approach of a passerby without fail is limited, and therefore, there is a problem that the approach of a passerby cannot be detected unless the passerby comes very close to the flexible display element **11**. In contrast to this, in the configuration in FIG. **14**B, it is possible to appropriately arrange the sensors **72**, **74** at desired positions, and therefore, it is possible to arbitrarily set a position at which the image display and the bent state are changed when a passerby approaches. However, in the case of FIG. **14**B, it is necessary to provide the interface **73** in the holding part **12** and there is a problem that the holding part of the conventional paper medium cannot be used. With the configuration in FIG. **14**C, the above-mentioned problems do not arise, however, it is not possible to arrange the sensor **74** at too great a distance because of the communication range available.

[0111] In recent years, an identification device called RFID is widely spread. The identification device outputs a wireless signal for excitation from a base apparatus, and the RFID generates electric power from the wireless signal and activates an internal circuit using the electric power and transmits stored data to the base apparatus. The base apparatus takes out information stored in the RFID from the received signal.

[0112] For example, in a limited space, such as an amusement park and zoo, with visitors' permission, RFIDs that store attribute data, such as visitor's sex and age, are attached to the visitors, and the sensors **71**, **72**, **74** are used as the base apparatus. The sensors **71**, **72**, **74** output wireless signals at all times and when a visitor carrying the RFID approaches the sensor, the sensor acquires the attribute data from the RFID and causes the flexible display element **11** to display an appropriate image in accordance with the data or to rewrite the display image so that an appropriate image is displayed, and further, to perform a bending motion in accordance with the display image. When a visitor approaches, the flexible display element **11** changes the display image and further performs a bending motion, and therefore, it is possible to display and emphasize information suitable for the approaching visitor as well as increasing the degree of attraction, and therefore, more appropriate information can be demonstrated.

[0113] The difference in the characteristics resulting from the difference in the configuration between FIG. **14**A to FIG. **14**C is the same as that in the case of the above-mentioned distance sensor.

[0114] It requires the consent of a passerby to attach an RFID to the passerby to carry it on a general road or roadway because of the security of personal data, and therefore, it is difficult to realize the above-mentioned system, however, it is possible within a specific shop, if an RFID is attached to a point card dedicated to the shop and a shopper carries the point card.

[0115] Further, by designing the sensors **71**, **72**, **74** so as to be capable of detecting temperature, smoke, noise, illuminance in the vicinity thereof and causing the flexible display element **11** to bend as well as displaying an image in accordance with the detection signal, it is possible to further magnify the display effect.

[0116] For example, when the sensor is a temperature sensor, a wind-bell or waves that move toward the shore are displayed on a hot day and a bending motion is performed in accordance with a display image. Further, an advertisement of cooling beverages is displayed and a bending motion is performed.

[0117] Further, by designing the sensor as a noise sensor, it is possible to rewrite the advertisement and increase the frequency of a bending motion based on the judgment that there are a lot of passersby when the detected noise level is high. On the other hand, when the detected noise level is low, it is judged that there are few passersby and the advertisement is rewritten and the frequency of bending motion is decreased to reduce power consumption.

[0118] Furthermore, on a reflection type display medium, such as cholesteric liquid crystal, displayed information is hard to see if the illuminance is low. Because of this, the sensor is designed as an illuminance sensor and when the detected illuminance level is high, a normal image is displayed and a bending motion is performed. On the other hand, when the detected illuminance level is low, an image intended to be used when the illuminance is low stored in the storage part **23** in advance, in which the character size is large, the line is thick, and the number of colors is small, is read and displayed and at the same time, a bending motion is performed in accordance with the display image.

[0119] The modified examples in which sensors are combined are explained as above, however, there can be various kinds of sensors and various combinations.

[0120] Further, information can be expressed not only by a display but by sound. Because of this, it is possible to further increase the degree of attention when providing information by combining an acoustic apparatus with the display system in the embodiment.

[0121] FIG. **15**A to FIG. **15**C are diagrams each illustrating a configuration of a modified example in which a speaker is combined with the display system in the embodiment. There can also be various modified examples according to the position at which the speaker is provided.

[0122] FIG. **15**A is an example in which a speaker **81** is provided in the display device **10** (flexible display element **11**). The control part **22** outputs a voice stream to the speaker **81** and the voice is output from the speaker **81**.

[0123] FIG. **15**B is an example in which a speaker **82** is provided outside the display device **10**. The control part **22** sends a voice stream to the speaker **82** via a wired interface **83** provided in the holding member **12** that holds the flexible display element **11**.

[0124] FIG. **15**C shows a configuration for transmitting a voice stream to a speaker **86** from the control part **22** using a wireless interface. The display device **10** includes a wireless transmission part **84** that outputs the voice stream output from the control part **22** as a wireless signal. To the speaker **86**, a wireless reception part **85** is attached, which receives the wireless signal of the voice stream transmitted from the wireless transmission part **84** and sends the received voice stream to the speaker **86**.

[0125] The control part **22** reads the image data, data of bending motion and voice data stored in a storage part, not illustrated schematically, and produces a display at a timing specified by the data and performs a bending motion and at the same time, sending a voice stream to the speaker **81** at a timing associated with the timing and outputting a voice signal. Due to this, it is possible to output music in accordance with the display image and perform a bending motion of the display device **10** to the accompaniment of the rhythm of the music, and therefore, the degree of attention can be further increased.

[0126] In the examples explained so far, such as the configuration in FIG. **1**A, the power source **21** is provided in the display device **10** and can be realized by a thin battery, such as a button cell. There can also be various modified examples of the power source.

[0127] FIG. **16** shows a configuration of a modified example that utilizes the non-contact electric power supply method described in patent document 2. There is provided a base power source **91** that outputs a high frequency signal for electric power outside the display device **10**. The display device **10** includes an electric power reception part **92** that receives the high frequency signal for electric power, rectifies the received high frequency signal for electric power, and generates a direct current. The electric power reception part **92** supplies the generated direct current power source to the power source **21** and the power source **21** accumulates the supplied electric power. When the accumulated electric power is running short, the base power source **91** is instructed to transmit a high frequency signal for electric power.

[0128] As illustrated in FIG. **17**, it may also be possible to provide a power source **93** outside the display device **10** and supply power source to the control part **22** and the actuator drive part **24** via a wired connector **94** provided at a part in contact with the holding part **12** of the flexible display element **11**. With this configuration, it is possible to increase the capacity of the power source **93** provided externally. However, it is not possible to use the conventional holding part for paper medium as it is.

[0129] FIG. **18** is a diagram illustrating still another modified example. In the configuration in FIG. **1**A, the power source **21**, the control part **22**, the storage part **23**, the actuator drive part **24** and the actuator **25** (**25**A to **25**D) are provided in the display device **10**, however, it is also possible to, as illustrated in FIG. **18**, provide only the display part and the actuator on the display element (electronic paper) **11** and provide the power source **21**, the control part **22** and the actuator drive part **24** externally (the storage part is not illustrated schematically), and then write an image to the display part from a control part **96** via the wired interface provided in the holding part **12** and drive the actuator **25** by the actuator drive part **24**.

[0130] As described above, the embodiments disclose a novel display element and a display system capable of further increasing the degree of attention in a display device that uses a flexible display element.

[0131] As described above, in the display device and the display system, there is provided a control part that causes a display part to perform a bending motion in accordance with an image to be displayed on the display part.

[0132] The control part is configured to cause the display part to perform a bending motion in accordance with an image, and therefore, it is possible to further increase the degree of attention.

[0133] The control part causes the display part to perform a bending motion by driving an actuator attached to the display part.

[0134] It is possible to cause the display part to bend into various shapes by attaching a plurality of actuators to the display part and causing the control part to selectively drive the plurality of actuators. Further, it is also possible for the

control part to cause the display part to perform a predetermined motion by driving the plurality of actuators in an interlocking manner.

[0135] Any actuator can be used, however, an actuator that is thin, light, and consumes less power is preferable and a piezoelectric actuator or thermal distortion actuator including a monomorph or bimorph structure can be used. An actuator including a monomorph structure can bend in one direction, however, an actuator including a bimorph structure can bend in both directions.

[0136] An actuator including a bimorph structure is configured so as to include a first piezoelectric element film formed on a first electrode, a common electrode formed on the first piezoelectric element film, a second piezoelectric element film formed on the common electrode, and a second electrode formed on the second piezoelectric element film.

[0137] When image data includes an emphasized display region, if the control part causes the region of the display part corresponding to the emphasized display region to perform a motion, such as a bending motion, it is possible to further increase the degree of attention.

[0138] It may also be possible to design the configuration so that data of bending motion includes information about the magnitude of a bending motion and the control part changes the magnitude of the bending motion in accordance with an image to be displayed on the display part.

[0139] It may also be possible to design the configuration so that data of bending motion includes information about the speed of a bending motion and the control part changes the speed of the bending motion in accordance with an image to be displayed on the display part.

[0140] Further, it may also be possible to design the configuration so that a detection sensor is provided in the display device or in the vicinity thereof and the control part causes the display part to display an image in accordance with a detection signal of the detection sensor and at the same time, causing the display part to perform a bending motion in accordance with the image. Due to this, for example, it is possible to suddenly produce a display when a passerby approaches and cause the display device to bend, and therefore, it is possible to further increase the degree of attention.

[0141] When a target is a passerby including an identification element, such as RFID, it is possible to produce a display in accordance with the target and thereby increase the degree of attention by designing the configuring so that a detection sensor further detects identification information and the control part causes the display part to display an image in accordance with the identification information and at the same time, causing the display part to perform a bending motion in accordance with the image.

[0142] When the display device includes a plurality of actuators, it is possible to rock the display part back and forth by continuously shifting the bending timing at which the control part causes the display part to bend. By rocking the display part back and forth in accordance with an image to be displayed, it is possible to further increase the degree of attention.

[0143] It may also be possible to arrange an optical element, such as a Fresnel lens, on the display surface in order to make more conspicuous a bending motion.

[0144] It is necessary for the display part to be flexible and can be realized by, for example, a liquid crystal display device that includes liquid crystal including a cholesteric phase and which displays an image by switching the state between a planar state and a focal conic state.

[0145] It is necessary for the display part to be flexible and desirable to be in the form of a sheet.

[0146] It is necessary to provide a display part and an actuator to the display element, however, there can be various modified examples depending whether a power source, a control part, a storage part that stores data of bending motion corresponding to image data, an actuator drive part, etc., are provided to the display element or to a part other than the display part. There can also be various modified examples depending on the method of supplying display data, data of bending motion, and power source.

[0147] For example, the display element is provided with a storage part that stores image data and data of bending motion corresponding to the image data, and the control part reads the image data and the data of bending motion corresponding to the image data from the storage part and causes the display part to display the image data and at the same time, causing the display part to perform a bending motion based on the image data and the data of bending motion.

[0148] It is also possible to design the configuration so that an information reception part that receives an input of information from outside is provided, and the information reception part receives information including image data and data of bending motion from outside and stores it in a storage part. The information reception part receives information from outside by a wireless or wired network. Further, it is also possible for the information reception part to receive a high frequency signal from outside, rectify the high frequency signal, and use it as a power source to display an image on the display part.

[0149] If the display device is configured so as to be arranged in a suspended state, it is easy to exchange a conventional paper medium with the device.

[0150] All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a illustrating of the superiority and inferiority of the invention. Although the embodiments of the present invention have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. A display device comprising:

a display part that displays an image; and

a control part that causes the display part to perform a bending motion in accordance with the display image.

2. The display device according to claim **1**, comprising an actuator attached to the display part, wherein

the control part causes the display part to perform a bending motion by driving the actuator.

3. The display device according to claim **2**, wherein:

the two or more actuators are provided to the display part; and

the control part selectively drives the two or more actuators.

4. The display device according to claim **3**, wherein

the control part drives the two or more actuators in an interlocking manner.

5. The display device according to claim **2**, wherein
the actuator comprises:
a first piezoelectric element film formed on a first electrode;
a common electrode formed on the first piezoelectric element film;
a second piezoelectric element film formed on the common electrode; and
a second electrode formed on the second piezoelectric element film.

6. The display device according to claim **1**, comprising a storage part that stores image data and data of bending motion corresponding to the image data, wherein
the control part reads the image data and the data of bending motion corresponding to the image data from the storage part and causes the display part to display the image data based on the image data and the data of bending motion and at the same time, causing the display part to perform a bending motion.

7. The display device according to claim **6**, wherein:
the image data comprises an emphasized display region; and
the control part causes the region of the display part corresponding to the emphasized display region to perform a bending motion.

8. The display device according to claim **6**, wherein:
the data of bending motion comprises information on the speed or amplitude of the bending motion; and
the control part changes the speed or amplitude of the bending motion in accordance with an image displayed on the display part.

9. The display device according to claim **1**, comprising a detection sensor, wherein
the control part causes the display part to display the image in accordance with the detection signal of the detection sensor and at the same time, causing the display part to perform a bending motion.

10. The display device according to claim **9**, wherein:
the detection sensor further detects identification information; and
the control part causes the display part to display an image in accordance with the identification information and at the same time, causing the display part to perform a bending motion in accordance with the image.

11. The display device according to claim **1**, wherein
the control part causes the display part to rock back and forth by the bending motion.

12. The display device according to claim **1**, comprising a lens arranged on the display surface.

13. The display device according to claim **1**, wherein
the display part comprises liquid crystal including a cholesteric phase and displays the image by switching the state between a planar state and a focal conic state.

14. The display device according to claim **1**, wherein
the display part is in the form of a sheet.

15. The display device according to claim **6**, comprising an information reception part that receives an input of information, wherein
the information reception part receives information including the image data and the data of bending motion from outside and stores the information in the storage part.

16. The display device according to claim **15**, wherein
the information reception part receives the information from the outside via a wireless or wired network.

17. The display device according to claim **15**, wherein
the information reception part further receives a high frequency signal from outside, rectifies the high frequency signal, and uses it as a power source to display an image on the display part.

18. The display device according to claim **1**, wherein
the display device is arranged in a suspended state.

19. A display system comprising:
a storage part that stores image data and data of bending motion corresponding to the image data;
a transmission side device comprising a data transmission part that transmits the image data and the data of bending motion stored in the storage part to a display device;
a reception part that receives the image data and the data of bending motion from the data transmission part;
a display part that displays an image corresponding to the image data; and
a control part that causes the display part to perform a bending motion in accordance with the data of bending motion.

20. The display system according to claim **19**, wherein
the transmission side device and the display device are connected via a wireless or wired network.

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